New Technologies for Sow Nutrition and Management[a]
- Review -

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ABSTRACT : Genetic selection and sophisticated management technology have produced modern sows which excel in litter size and milk production. Recent research has identified nutritional innovations which may enhance productivity of the high producing sow. Selected research in three areas which have the potential to enhance reproductive performance are summarized in this report. First, preliminary evidence indicates that organic chromium may enhance litter size and conception rate. Secondly, high producing sows, particularly primiparous sows, required higher protein/lysine in late gestation and or lactation to optimize weaning weight and subsequent litter size. Valine and isoleucine, but not leucine, have been shown to enhance milk production. Phased feeding programs with diet cost partitioned toward gilts and away from parity 3 to 8 sows have been suggested as a means of improving reproductive performance in young sows. Lastly, recent research with sufficient sow numbers to document the effect of dietary fiber on reproductive performance has shown that sows fed fiber farrowed and weaned more pigs. *(Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 6 : 956-965)*

Key Words : Sow, Nutrition, Management, Reproductive Performance

INTRODUCTION

Recent research in the area of sow nutrition and management has provided exciting advancements in our understanding of nutrient requirements and management systems which may enhance performance. This manuscript will summarize selected sow research in the areas of organic chromium, protein and amino acid nutrition, and fiber. Recent publications in each of these areas have provided evidence that implementation of these technologies may enhance reproductive performance.

ORGANIC CHROMIUM

The impact of organic chromium supplementation on glucose metabolism and insulin sensitivity has been documented in swine. Amoikon et al. (1995) used classical methodologies involving Intravenous Glucose Tolerance Test and an Insulin Challenge Test to document the effect of chromium picolinate on glucose metabolism. Glucose disappearance rate was increased and glucose half-life was decreased in pigs fed 220 ppb chromium picolinate confirming an improvement in insulin sensitivity.

Insulin function has been associated with improved ovulation rate and litter size in recent studies. Exogenous insulin has been demonstrated to increase frequency of LH pulses and ovulation rate of gilts (Britt et al., 1988). Similarly, Cox et al. (1987) observed an increase in ovulation rate in gilts in response to pre-estrus' administration of insulin. Ramires et al. (1994) observed an increase in litter size in response to insulin administration from weaning of the first litter to remating. Improved insulin function may explain the mechanism whereby organic chromium elicits an effect on litter size.

Lindemann et al. (1995a) used gilts for a reproductive study which were previously involved in a growing/finishing trial where a level of 200 ppb chromium was fed. Gilts were continued on a level of 200 ppb chromium from chromium picolinate for two parities. Blood samples taken at mid-gestation demonstrated differences in tissue responsiveness to insulin (table 1) with gilts receiving chromium having greater tissue sensitivity to insulin. Garcia et al. (1987) has confirmed the effect of chromium on altering insulin function (table 2). In addition, dietary chromium picolinate reduced uterine secretion of oxytocin in response to an estrogen challenge. These studies suggest that dietary organic chromium may have effect on insulin function which may explain the effects on reproductive performance.

EFFECT OF ORGANIC CHROMIUM ON REPRODUCTIVE PERFORMANCE

Lindemann (1997) provided an excellent review of studies to date with organic chromium in sow diets. In the initial study, gilts were retained from a growing/finishing study and were continued on 200 ppb chromium from chromium picolinate. An increase of 2.2 pigs/litter born and 2.1 pigs/ litter weaned was observed (Lindemann et al., 1995a; table 3).

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[a] This paper has been presented at Symposium IV entitled "Recent Advances in Swine Production Systems" of the 8th World Conference on Animal Production on June 30, 1998 at Seoul National University, Seoul, Korea.

Table 1. Effect of chromium supplementation on serum glucose and insulin values in gestating gilts[ab]

Response:	Glucose		Insulin		Insulin/Glucose	
Cr supplementation, ppb	Fasting	Postfast	Fasting	Postfast	Fasting	Postfast
0	83.8	86.6	67	353	0.80	4.12
200	82.0	80.7	57	127	0.68	1.56
P-values	0.43	0.13	0.60	0.01	0.63	0.01

[a] Glucose values are mg/100ml and insulin values are pg/ml. [b] Adapted from Lindemann et al., 1995a.

Table 2. Effects of Chromium picolinate on insulin function[a]

	Supplemental Chromium picolinate, ppb				Pooled SE
	0	100	200	500	
Insulin/Glucose 2 hr postfeeding	0.71[b]	0.43[b]	0.37[c]	0.29[c]	0.1
Uterine oxytocin, pg/ml	29460[b]	4172[c]	11899[c]	3917[c]	7971

[a] Adapted from Garcia et al., 1997; glucose values are mg/100 ml and insulin values are μIU/ ml/mg glucose/dl.
[b,c] Means without a common superscript differ ($p<0.05$).

Table 3. Effect of organic chromium on litter size in swine

Organic Cr from Chromium picolinate, ppb:	0	200
Trial 1		
Litter size		
Total born[a]	9.6	11.8
Born live[a]	8.9	11.2
Day 21[a]	8.2	10.3
Litter weight, lb		
Total born[a]	30.4	37.5
Born live[a]	28.4	35.9
Day 21[b]	102.5	120.4
Trial 2		
Litter Size		
Total born	10.7	11.3
Born live (see below)	9.6	10.5
Day 21	9.0	9.5
Litter weight, lb		
Total born	36.2	37.0
Born live	34.0	35.5
Day 21	111.1	120.6
Born live by parity		
Parity 1	9.2	9.6
Parity 2	9.7	10.5
Parity 3	10.4	12.4
Combined	9.6	10.5

Adopted from Lindemann (1997).
[a] Means differ ($p<0.05$). [b] Means differ ($p<0.10$).

In a second study (Lindemann et al., 1995b) using gilts which had not previously been supplemented with chromium, the response was smaller in parity 1 (0.4 pigs/litter) but increased through parity 3 (0.80 pigs/litter in parity 2 and 2.0 pigs/litter in parity 3). Although differences were not significant in this study, the trends were similar to those observed in the initial study and suggest that some time period after initiating treatment may be necessary to elicit a response. The increase in litter size in both of these studies was observed after 6-7 months supplementation with organic chromium.

A study by Campbell (1996) with supplementation of 200 ppb chromium picolinate initiated the day after breeding also failed to elicit a response in litter size for a single parity (table 4). However, an improvement in farrowing rate was observed due to chromium supplementation. A follow-up single-parity study involving 1,606 sows that were supplemented for only 35 days postbreeding observed a smaller increase in farrowing rate with chromium supplementation (82.0 vs 86.3%, p=0.12).

Table 4. Effects of Cr from chromium picolinate and reproductive age of sow on reproductive performance

Parity of supplementation:	1		2	
Cr supplementation. ppb:	0	200	0	200
Farrowing rate, %[a]	79.0	92.0	79.0	95.0
Total born/litter[b]	10.34	10.27	10.87	11.10
Born alive/litter[b]	9.58	9.66	10.30	10.36

Adapted from Campbell. 1996. Sows were supplemented for only one parity, it being either their first or second parity of production.
[a] Chromium effect, $p<0.001$. [b] Parity effect, $p<0.001$.

A field trial with chromium yeast as the chromium source (Lindemann, 1997) comparing no supplemental chromium, 200 ppb chromium from chromium yeast during the first 30 days of gestation and lactation and 200 ppb chromium during all of gestation and lactation indicates that chromium yeast may also be an organic chromium source to consider. This study used only sows and was for one parity. Numerical improvements in both farrowing rate and litter size were observed (table 5) although a statistical evaluation was not performed.

Table 5. Effects of Cr yeast on sow performance

	Cr from Cr yeast, 200 ppb		
	None	Lactation/ 30 d gestation	Lactation/ All gestation
Sows mated, n	27	16	29
Weaning-mating interval, d	5.3	6.2	6.0
Farrowing rate, %	77.8	81.3	89.7
Born live per litter	9.6	10.8	10.8

These preliminary studies with organic chromium in sow diets suggest the potential for large improvements in reproductive performance although the limited number of studies, limited replicates in some studies, and variability in response should lead to caution in interpreting the results. Confirming these studies in additional trials should prove to be exciting and offers the potential for a major advancement in reproductive performance.

RECENT GESTATION AND LACTATION NUTRITION RESEARCH FINDINGS

Modern sows are younger and leaner at time of mating, have poorer appetites, are more fertile and produce more milk during lactation (Whittemore, 1996). Many recent investigations have established that sows, especially primiparous sows that lose excessive amounts of live weight or body condition (protein/fat) during lactation will have extended remating intervals, show reduced pregnancy rates and reduced embryo survival (Cole, 1990; Everts, 1994; Foxcroft et al., 1995; Close and Mullan, 1996). This paper reviews several nutritional factors affecting reproductive performance of high producing sows.

FEEDING DURING PREGNANCY

Early pregnancy

A high feeding level in early pregnancy may adversely affect embryo survival. Jindal et al. (1996) increased feed intake from 1.9 to 2.5 kg/d to day 15 days of pregnancy in gilts and observed a reduction in embryo survival at day 15 (86 vs 67%) with fewer viable embryos at day 25 (12.3 vs 9.8). This is consistant with recent reports by Ashworth (1991) and earlier research reported by Dyck et al. (1980). A high feeding level during the first 24-48 h after mating appears detrimental to litter size in gilts. Baidoo et al. (1992) however, found that sows fed low feed intake during lactation (3 kg/d) had more embryos and improved survival if fed a high level (3.6 kg/d) in early pregnancy. The fewest embryos and greatest embryo mortality were associated with sows on a low plane of feeding in both lactation and gestation.

Boyd and Touchette (1997) have suggested a practice of feeding at or below 1.5×maintenance to 21 days in gilts and sows (2.0 kg/d). Females that are extremely thin may benefit from a higher plane of feeding (3.5 kg/d).

Mid pregnancy

The nutritional strategy for mid-pregnancy should achieve moderate growth and reclaim body reserves. Plane of nutrition between day 20-50 of pregnancy may be important to muscle fiber number in piglets at birth and thereby potential postnatal growth. Severe feed restriction of pregnant sows reduces postnatal growth (Pond et al., 1985; Pond and Mersmann, 1988). Dwyer et al. (1994) reported that doubling feed intake between day 25-80 of pregnancy will enhance secondary muscle fiber numbers at birth and growth and efficiency of gain from 20-80 kg (table 6). This improvement in performance was not confirmed, however, in a recent study reported by Boyd and Touchette (1997). This study reported no difference in performance of progeny from sows fed 2.6 or 5.2 kg/day from day 25 to 80 (table 7).

Table 6. Effect of feed intake from day 25 to 80 on average daily gain and gain/feed ratios of 130-day-old pigs for linear growth phases[a]

	Level of feed		
Item	Control	HT[b]	P value
ADG (g/d)			
Weaning to d 70	467.4±18.35	465.4±14.59	NS[c]
Days 70 to 130	840.1±17.48	924.4±18.75	0.017
Gain/feed	0.401±0.007	0.433±0.011	0.025

Adapted from Dwyer et al., 1994.
[a] Students *t*-tests. [b] HT=High intake at d 25 to 80.
[c] NS=not significant (p>0.05).

Table 7. Effect of feed intake in pregnant sows (d 25-80) on postnatal growth in progeny

	Feed Level		
Item	Standard	High	SEM
No. sows	7	7	-
No. pigs tested	32	32	-
Progeny Growth			
Gain, g/d	875	875	14
FCR	2.23	2.21	0.03
P_2 Fat, mm	10.6	10.4	0.5
Lean %	57.2	56.8	0.6

Boyd and Touchette (1997)

Increasing feed intake may not have any effect on the number of fetuses, placental or fetal weight, or crown-rump length (Musser et al., 1997).

Late pregnancy

Nutrient needs increase substantially in late pregnancy. Sows fed at about maintenance (6.0 Mcal DE/d, 182 kg bw) were shown to be in negative energy balance in late pregnancy (Noblet et al., 1990). Noblet et al. (1990) suggested that the daily energy intake required to prevent mobilization of body fat in late gestation was 7.3 Mcal DE/d and Cole (1990) estimated that up to 9.5 Mcal DE/d was needed from day 90 to parturition to maintain P_2 fat in sows. Hughes (1993) reported that a P_2 fat depth below 12 mm at farrowing and below 10 mm at weaning compromised wean to estrus interval (>2d) and subsequent litter size (>2 pigs) in sows (table 8).

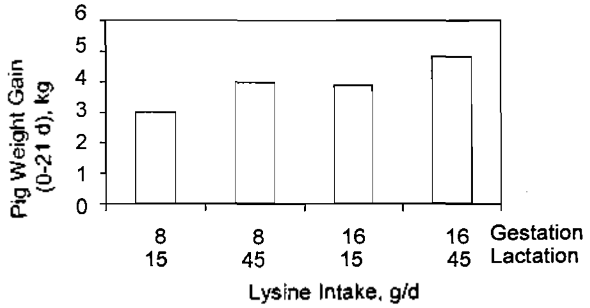
Table 8. Relation between fat depth at farrowing and weaning and reproduction in sows[a]

Fat Depth, P_2 mm	Wean to Estrus, d	Subsequent Litter Size	
		Total Born	Born Alive
Lactation, d1			
<12	8.5	9.1	8.5
12 to 16	6.6	11.8	10.8
>16	6.1	12.0	10.3
Wean, d 27			
<10	8.1	9.9	8.9
10 to 13	6.7	11.1	9.9
>13	5.8	12.7	11.4

Adapted from Boyd and Touchette (1997).

[a] 76 LW×LR sows (parity 2-6) with 9.5 pigs weaned. Hughes, 1993.

Protein needs are also increased with advancing pregnancy. Noblet et al. (1990) estimated that nitrogen retention increased from 2 g/d at mid-pregnancy to 14 g/d in late pregnancy. Protein restriction of gilts during pregnancy (16 vs 8 g/d) led to reduced piglet growth rate (figure 1).



Adapted from Boyd and Touchette (1997)

Figure 1. Protein restriction in pregnancy reduces lactation performance

Some small positive effects on birth weight and survival (Cromwell et al., 1989) have been demonstrated with increased feeding level in late gestation. Neil (1996) also reported that feeding sows *ad libitum* from day 111 of gestation until weaning did not adversely affect sow or litter performance and resulted in overall greater feed intake than did a system of feeding sows restricted levels of feed before farrowing and in early lactation. Boyd and Touchette (1997) have suggested a nutritional strategy that conserves body reserves until a better understanding of the relationship between body protein mass and subsequent litter size and milk production is developed.

Lactation

Because the demand for nutrients during lactation is high to maintain milk production, the intake of protein/amino acids during lactation is critical for overall lactation performance. In an earlier study (NCR-42, 1978), no benefit to increasing dietary crude protein levels during lactation on 14 day piglet weight gain was observed. This is not surprising given that the average litter size was 7.5 (table 9).

Table 9. Effect of lactation protein level on reproductive performance

	12 CP/ 0.55 L	16 CP/ 0.80 L	20 CP/ 1.03 L
All parities			
Live pigs/litter	8.93	8.31	9.23
Birth weight, kg	1.40	1.44	1.38
Pigs at 14 days	7.47	7.31	7.45
14d piglet wt. gain, kg	2.40	2.37	2.40
Parity 1 deleted			
Live pigs/litter	9.57	8.84	10.09
Birth weight, kg	1.48	1.49	1.39
Pigs at 14 days	8.28	8.08	7.57
14d piglet wt. gain, kg	2.30	2.32	2.59
Av. feed intake, kg/d	4.59	4.58	4.87

(NCR-42, 1978)

Re-evaluation of the nutritional needs of lactating sows has received increased interest in the last decade due to the utilization of prolific sows. Because lysine is typically the first limiting amino acid for lactating sows, many studies have evaluated graded levels of dietary crude protein during lactation in an attempt to evaluate the response of sows to lysine intake. Stahly et al. (1990) observed typical responses to increasing protein and lysine in sows nursing large litters (table 10).

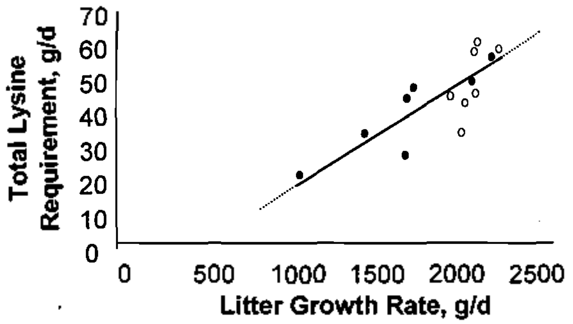
Pettigrew (1993) developed a regression equation based on published studies that related maximum litter growth rate achieved to the maximum lysine need.

The data appeared as a normal response curve which gave rise to the relationship: 26 g dietary lysine/kg litter growth/day. Boyd and Touchette (1997) updated the data set to include seven recent publications (figure 2). This allows the nutritionist to relate minimum lysine needs (g/d) to actual feed intake to drive a dietary lysine percentage for diet formulation. Data by King et al. (1993) also indicate that the lysine level for optimum milk production (litter growth) is lower than is required to minimize body protein loss (Nitrogen balance; figure 3). This is supported by the data from Touchette et al. (1996), who observed that lysine needed for minimum weight and loin muscle loss (50-54 g/d) was much higher than needed to maximize litter growth rates.

Table 10. Lactational responses to sows nursing large litters

CP	10.7	13.0	15.3	17.7
Lysine	0.42	0.58	0.75	0.92
CP, g/d	640	780	920	1060
Lysine, g/d	19.9	28.9	36.6	46.7
ME, Mcal/d	17.4	17.9	17.5	18.2
No. pigs, d27	10.5	10.4	10.5	10.8
Sow wt. change, kg	-19.6	-13.0	-7.0	-4.5
Litter wt. gain, kg	40.1	41.7	44.6	50.1
% return to estrus, ≤ 14d	80.8	84.0	88.5	83.3

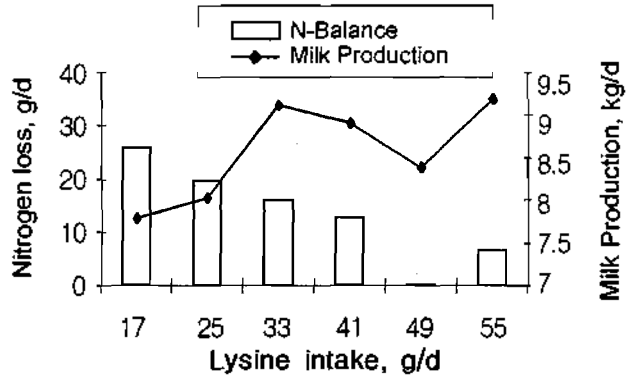
6 kg FI/d. Stahly et al., 1990



Adopted from Boyd and Touchette (1997)

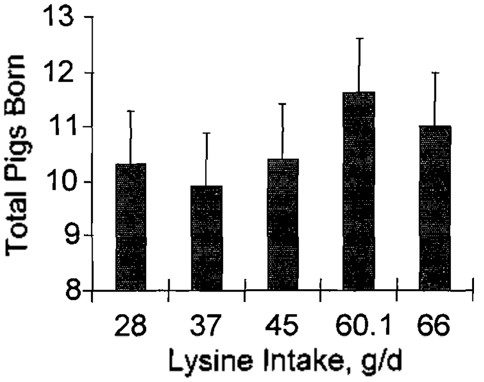
Figure 2. Estimation of total lysine requirement of lactating sows in relation to litter growth

Recent data from Tritton et al. (1996) show a connection between minimum protein mobilization in lactation and subsequent litter size. Primiparous females fed 60-66 g/d lysine during lactation had more pigs at the next farrowing when compared to those fed 28-45 g/day (figure 4). Touchette et al. (1997) observed that an intake of 52 g/d was necessary to maximize litter size (vs ≤ 42 g/d). These studies suggest that lysine levels higher than necessary for maximum milk production may be essential to minimize nitrogen loss and to optimize subsequent litter size.



Adapted from Boyd and Touchette (1997)

Figure 3. Lysine response by milk production and nitrogen balance (King et al., 1993)



Adapted from Boyd and Touchette (1997)

Figure 4. Dietary lysine intake during first lactation and second litter total born (Tritton et al., 1996)

Feeding strategies during lactation should be to maximize feed intake. Koketsu et al. (1996) suggest that the importance of lactation feed intake on subsequent reproductive output increases as weaning age decreases. Aherne (1994) in a review of five studies reported that increasing feed intake of primiparous sows from 4.5 to 5.5 kg/d increased second parity litter size from 10.2 to 11.2 pigs.

Valine

Three recent experiments have confirmed that the valine requirement of the high-producing lactating sow is higher than previously thought. Tokach et al. (1993) observed an increase in litter weaning weights in response to a dietary valine concentration form 0.60% to 0.90%, in a sow lactation diet containing 0.90% lysine. The valine effect was greater in litters of more than 10 pigs weaned emphasizing that the primary concern with valine is in sows producing larger litters. A follow-up study was conducted in cooperation with the University of Minnesota (Rechert et al., 1996). Crystalline valine replaced corn starch to provide for dietary valine levels ranging from 0.75 to 1.15%. Mean litter size after adjustment was 10.3 pigs across treatments. Sow feed intake, body weight change, tenth-rib backfat change and days to estrus were not affected by dietary valine levels. Litter weaning weight increased in a linear fashion as dietary valine increased with the greatest proportion of response observed as valine increased to 1.05% of the diet, an increase of 2.6 kg over that observed in litters from sows fed the basal diet (table 11).

Table 11. Effect of valine concentration in sow diets on litter growth (Richert et al., 1996); total 203 litters (40 or 41 per treatment)

	Dietary valine (%)					CV
	0.75	0.85	0.95	1.05	1.15	(%)
Litter growth to 21 d (kg)[1]	46.9	47.1	48.3	49.5	49.6	13.9
Litter weaning weight at 21 d (kg)[1]	62.4	62.6	64.0	65.0	65.5	11.9

[1] *Linear effect of valine, $p<0.05$.*

A subsequent study was conducted to determine whether the response to valine differed with increasing dietary lysine (Richert et al., 1997a). Treatments were arranged in a 2×3 factoral with two levels of lysine (0.8 or 1.2%) and three VAL:LYS ratios (80, 100 or 120). Results (table 12) show that high dietary levels of both lysine and valine are necessary to maximize litter growth under conditions of high milk production, but not when milk production is lower.

Recent research with isoleucine in sows nursing large litters (10.9 pigs weaned) has suggested that, like valine, it may be required in greater amounts than previously recommended to maximize litter weight. Richert et al. (1997b) fed diets to sows that were formulated to contain 0.90% lysine with either 0.72 or 1.07% valine in combination with 0.50, 0.85 or 1.20% isoleucine. Litter weight gain increased with increasing levels of either valine or isoleucine (table 13). At the higher level of valine (1.07%), the response to isoleucine was maximized at 0.85%.

These studies suggest that among the branched chain amino acids, both valine and isoleucine but not leucine (Kerr, 1997) appear to increase milk production as indicated by increased litter weight gain. On average, litter weight was increased by approximately 2 kg at optimal levels of dietary isoleucine or valine when compared to sows receiving basal levels of isoleucine or valine. It is interesting to note that these amino acids (isoleucine and valine) can be metabolized to succinyl-CoA and therefore can potentially serve as a source of energy for the mammary gland.

The voluntary feed intake of modern primiparous sows is low and generally results in nutrient output exceeding nutrient input. Studies have shown that sows, especially primiparous sows, which loose excessive weight (protein and lipid) will have extended remating intervals, a lower percentage of sows in estrus within 10 days of weaning, reduced pregnancy rate and reduced embryo survival (Einarsson and

Table 12. Effect of lysine and valine concentrations in sow diets on litter growth (kg) between days 2 and 24 of lactation (Richert et al., 1997a)

Lysine (%)	80			1.2			CV (%)
Valine/lysine (%)	80	100	120	80	100	120	
≥10 pigs/ litter[1]	47.5	46.0	49.7	51.3	49.8	55.7	14.5
<10 pigs/litter[2]	41.1	42.3	41.4	40.5	45.3	39.8	17.5

[1] Lysine effect ($p<0.001$); valine effect (linear $p<0.05$; quadratic $p<0.05$). Range of 19 to 25 litters per treatment.

[2] Range of 10 to 14 litters per treatment.

Table 13. Increasing dietary valine and isoleucine for the high producing lactating sow

LYS	0.90						
VAL	0.72			1.07			1.42
ILE	0.50	0.85	1.20	0.50	0.85	1.20	0.50
Lactation FI, kg/d	6.2	6.1	6.3	6.0	6.2	5.9	6.2
Litter wt. Gain, kg	44.3	45.4	46.4	45.4	48.0	48.0	47.1

10.9 pigs/litter, 20.3 day lactation.

Reichert et al., 1997b.

Rojkittikhun, 1993; Neil, 1996). It has been suggested that a strategy should be employed which targets weight and backfat gain of each sow during gestation which may vary with parity in a phased concept (Aherne, 1997). Boyd and Touchette (1997) have suggested a parity feeding program based on the predicted energy and lysine needs. These researchers suggest separation of sows by parity (1, 2 and 3-8) each with different lactation and gestation diets. Diet cost is partitioned toward gilts and away from parity 3 to 8 sows.

ROLE OF FIBER IN IMPROVING REPRODUCTIVE EFFICIENCY

Preweaning mortality in swine varies from 13 to 25% of the pigs born alive (Boyd, 1979) with 60% of this loss occurring within the initial 3 to 4 days after birth (Pomeroy, 1960; England, 1986; USDA, 1992). Enhancing neonatal energy stores by maternal dietary manipulation has shown promise in improving pig survival. Nutritional manipulations of the gestating sow diet with 1-3-butanediol (Stahly et al., 1980, 1982; Rosebrough et al., 1981) or medium chain triglycerides (Newcomb et al., 1991; Azain, 1993), which elevate plasma ketogenic substrates, or with organic acids (Spence et al., 1985) have been shown to have glucose-sparing effects providing additional metabolites in maternal plasma which may increase nutrients available for fetal growth and energy storage. Ketogenic substrates have the potential to both stimulate lipogenesis and spare carbohydrate for nonoxidative functions (Allee et al., 1972; Seccombe et al., 1977; Shambaugh, 1985) and have also been used postnatally to improve survival by direct administration to the pig within 24 hours after birth (Benevenga et al., 1989; Odle et al., 1989). These dietary alterations have increased pig survival to day 7 and 21 (Stahly et al., 1980, 1982; Rosebrough et al., 1981; Azain, 1993).

Numerous lower-cost byproducts with high fiber content are available, and energy intake constraints do not limit dietary fiber levels during gestation. Therefore, feeding high fiber diets during gestation or feeding dietary fiber supplements which can increase volatile fatty acid (VFA) production may be a more feasible means of dietary manipulation to provide ketogenic energy substrates for the developing fetus. Short chain acids (acetate and lactate) have been shown to be as effective as 1-3-butanediol in increasing neonatal pig total liver glycogen (Spence et al., 1985). The VFA produced by fermentation can provide up to 28% of the energy requirements for growing pigs (Imoto and Namioka, 1978). Sows digest crude fiber more efficiently than the growing pig (Fernandez et al., 1986), and have a higher fermentation capacity in the hindgut, because of their low feed intake and resulting slow rate of passage (Shi and Noblet, 1993).

Recent regional research involving 8 research stations (699 litters) evaluating one fiber source for gestation (wheat straw) over three reproductive cycles confirmed the efficacy of fiber addition to sow diets (Ewan et al., 1996). Wheat straw is a relatively non-fermentable fiber source and was assumed to contribute no nutrients to the diet. Straw was ground to a fiber length of 6 to 12 mm. All sows were allowed ad libitum access to a corn-soybean meal diet during lactation. Sows fed wheat straw during gestation consumed more feed during lactation (table 14). In addition, sows fed wheat straw during gestation farrowed more live pigs in cycle 2 (10.5 vs. 9.0) and 3 (10.6 vs. 10.0) but not in cycle 1 (9.9 vs. 10.4) which resulted in a significant diet × parity interaction.

Table 14. The effect of wheat straw fed to gestation sows[a]

	Diet	
	Corn-soy	Corn-soy + wheat straw
No. litters	346	353
Sow Traits		
ME/d, Mcal[b]	6.0	6.0
NDF, %[c]	8	18
Gestation wt. Gain, kg	40	35.9
Lactation wt. Loss, kg	4.09	4.09
Lactation feed/d, kg[d]	5.68	5.82
Litter traits		
Pigs born alive[e]	9.8	10.3
Pigs weaned[f]	8.4	9.1
Pig birth wt, kg	1.54	1.50
Pig weaning wt, kg	7.27	6.95

[a] Ewan et al., 1996, [b] Metabolizable energy intake.

[c] Dietary neutral detergent fiber (as-fed basis),[d] $p<0.106$.

[e] Treatment x parity interaction ($p<0.10$), [f] $p<0.01$.

Sows fed wheat straw also weaned more pigs than control sows. This is one of the few studies with fiber where the number of sows/treatment was large enough to detect a 0.5 to 1.0 pig/litter difference in litter size. In addition, energy and nutrient intake were not confounded with the effect of fiber.

Reese (1996) provided an excellent review of data where fiber sources were evaluated from more than one location (table 15). In general, all fiber sources with the exception of alfalfa meal and distillers grains tended to improve numbers of pigs born alive and number of pigs weaned.

Sohn et al. (1992) observed improved reproductive performance in sows fed 0.3% psyllium, a natural fiber laxative, for 14 days prior to farrowing and throughout lactation. This indicates that concentrated fiber sources fed at low dietary levels may have effects similar to those observed in sows fed high fiber diets. In addition, feeding low levels of a concentrated fiber source may avoid the detrimental effect of energy dilution observed in sows fed high fiber diets during lactation (Calvert et al., 1985).

Table 15. Average change in litter size according to source of dietary fiber fed to the sow during gestation

Fiber Source	Daily NDF intake, g[a]		No. pigs born alive	No. pigs weaned	No. litters[b]
	Control	Fiber			
Alfalfa meal	264	381	-0.4	-0.7	269
Alfalfa hay/ haylage	246	721	+0.5	+0.8	647
Corn gluten feed	166	794	+0.7	+0.4	229
Distillers grains	139	418	-0.3	-0.4	118
Oat hulls/oats	260	1221	+1.8	+0.7	96
Wheat straw	150	368	+0.5	+0.7	699

[a] Average neutral detergent fiber intake by the sow consuming control and fibrous diets during gestation.

[b] Total number litters produced by sows fed control and fibrous diets.

Another potential benefit of dietary fiber is illustrated by the research of Brouns et al. (1994) who evaluated the effects of feeding diets containing beet pulp on stereotypic behavior exhibited by gilts during the first 1.5 hours after feeding (table 16). These results indicate that inclusion of sugar beet pulp promoted satiety and reduced incidence of stereotypes.

Table 16. Effect of dietary fiber on the incidence of oral behaviors in sows[a,b]

Treatment	Time (min) spent on[c]		
	Licking	Sham-chewing	Bar-biting
Control (4.4 lb/d)	28.1	12.1	8.8
Restricted SBP (5.1 lb/d)	6.1	0.9	0.1
Ad libitum SBP	2.6	0.0	0.3
	p<0.03	p<0.08	p<0.05

[a] Brouns et al., (1994).

[b] SBP=unmolassed sugar beet pulp.

[c] During first 1.5 hr after feeding.

Another potential benefit from feeding fibrous diets to sows during gestation is the increased ability of the sow to consume more feed during lactation. Feed intake during lactation was enhanced by feeding gestation diets containing high levels of alfalfa-orchard grass hay (Holzgraefe et al., 1986), high levels of corn gluten feed (Honeyman and Zimmerman, 1990), and wheat straw (Yan et al., 1995; Ewan et al., 1996). This effect may be due to lower gestation weight gain because the efficiency of energy utilization is lower when fibrous feeds are added to sow diets (Etienne, 1987), reduced backfat deposition during gestation (Pollmann et al., 1979; Holzgraefe et al., 1986) or to an enhanced appetite during lactation by an increased digestive tract capacity (Kuan et al., 1983).

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